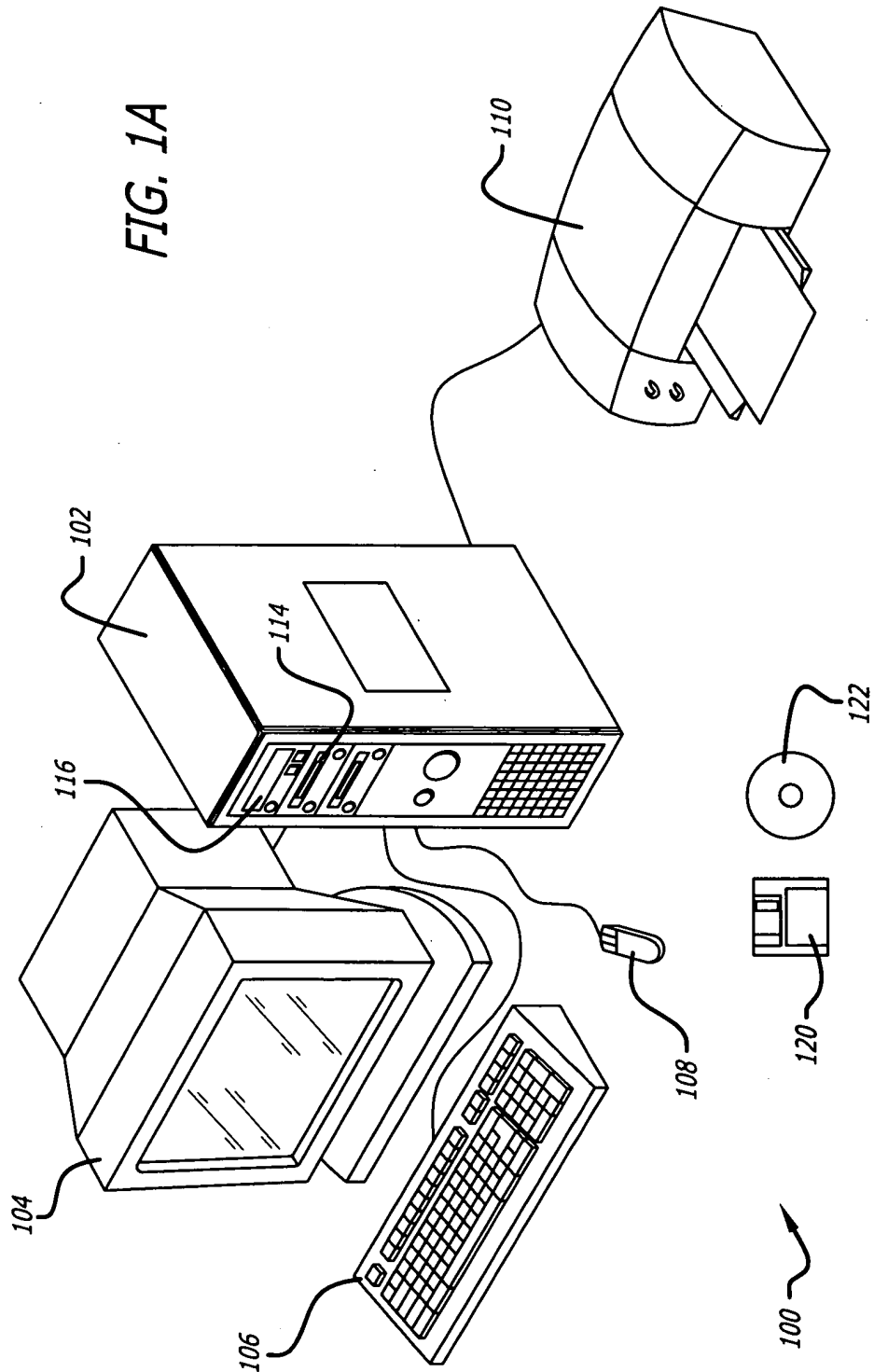




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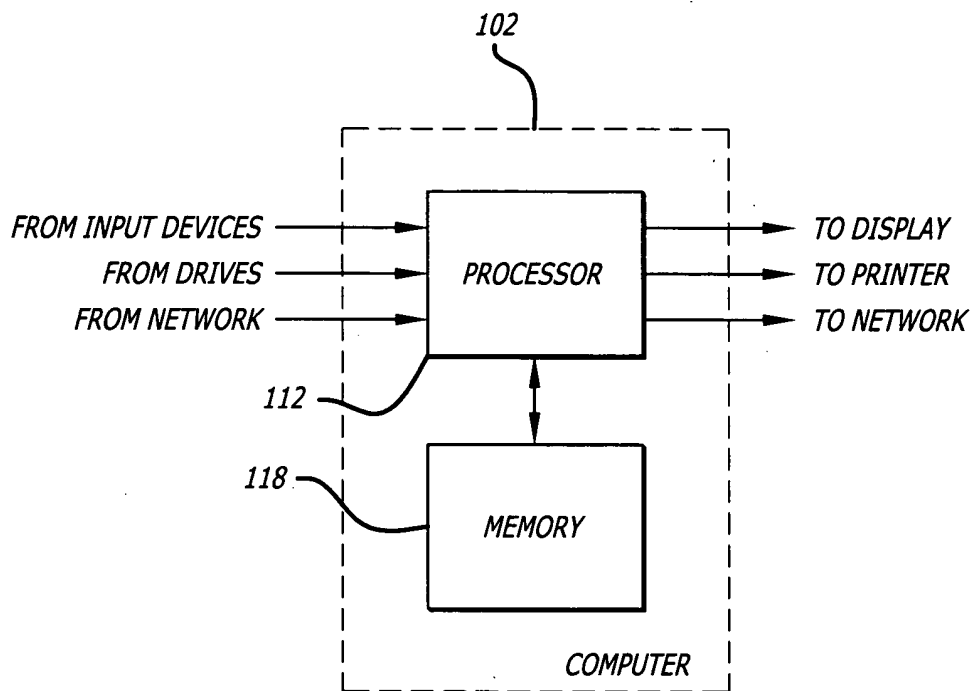


FIG. 1B

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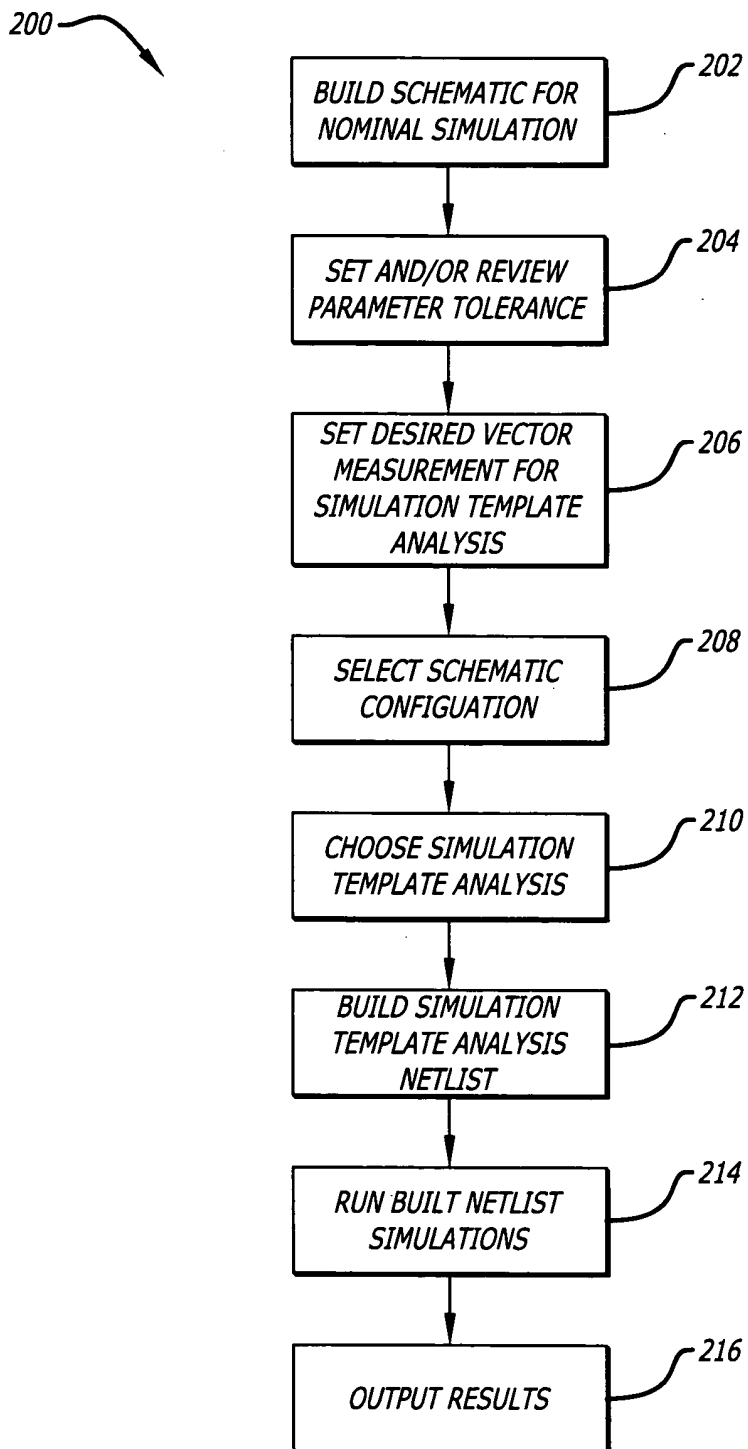


FIG. 2

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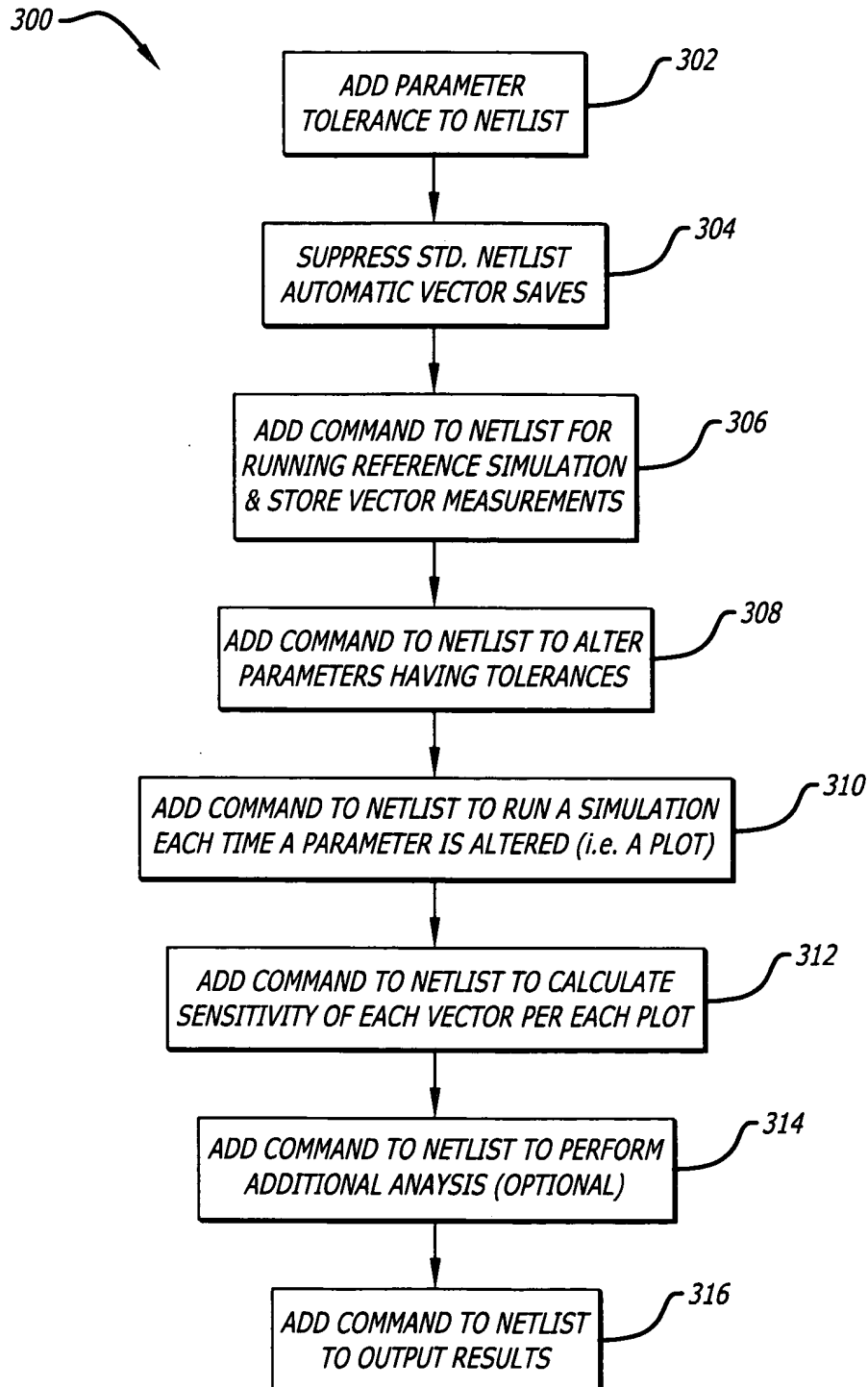


FIG. 3

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SENS, sensitivity analysis Simulation Template With Comments:

**Instruct the netlist builder to show tolerances*
 #tolerance 402

**Suppress automatic vector saves*
 #nosave 404

**Suppress IsSpice4 printout*
 #noprint 406

**Save vectors needed for measurements*
 #vector 408

**Set the output file pointer to the beginning to remove
 * the input net list*
 set rewind 410

**Set the noecho environment for print formatting*
 set noecho 412

**Run the specified simulation and save the results*
 #simulation
 set printmode = save
 #mprint 414

**Rename the simulation plot*
 nameplot ref 416

**Set the print format*
 SET COLWIDTH=22
 SET SPICEDIGITS=5 418

**Tell the user where we are*
 printstatus -t #####_sensitivity_for_each_parameter_##### 420

**Loop through all of the parameters*
 nextparam null
 while param < null
 **Alter each parameter*
 alterparam tolerance(param)/3
 **Simulate*
 #simulation
 Save the parameter reference in the new plot
 paramvec = param
 **Tell the user where we are*
 printstatus -p paramvec
 **Save the data*

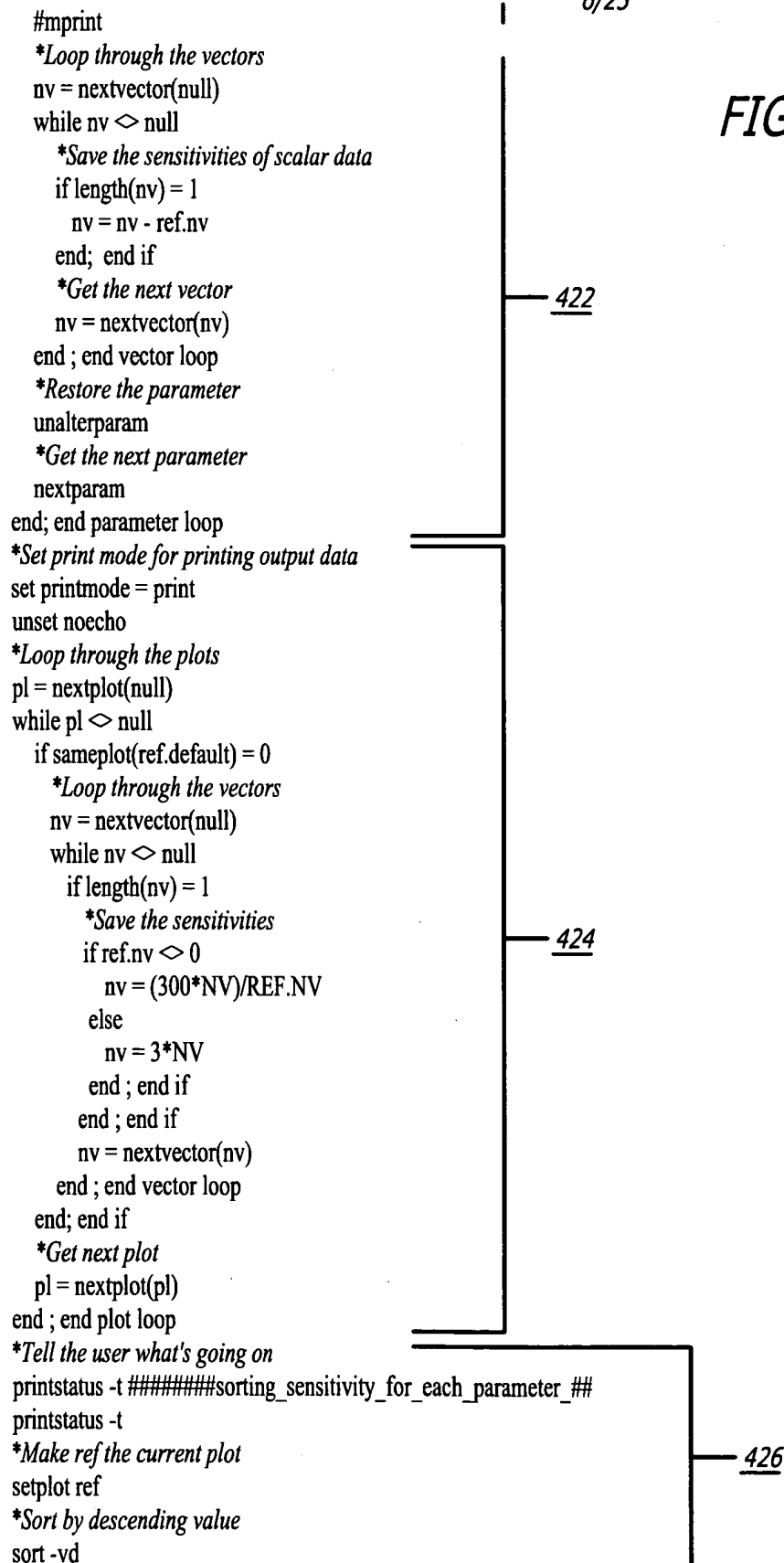
422

FIG. 4-1



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FIG. 4-2



```

*Loop through the plots
pl = nextplot(null)
while pl <> null
    if sameplot(ref.default) = 0
        *Print Headers
        SETPARAM PARAMVEC
        printstatus -p paramvec
        ECHO
        ECHO -u "*****SENSITIVITY DATA*****"
        ECHO
        ECHO -un "PARAMETER NAME: "
        PRINTNAME PARAMVEC
        ECHO
        ECHO -un " NOMINAL VALUE: "
        PRINTVAL PARAMVEC
        ECHO
        ECHO
        PRINTTEXT -u VECTOR SENSITIVITY%
        ECHO
        ECHO
        *Sort by descending data value
        sort -vd
        *Loop through the vectors and print data
        nv = nextvector(null)
        while nv <> null
            if length(nv) = 1
                if ref.nv < 0
                    PRINTNAME NV
                    PRINTVAL NV
                else
                    PRINTNAME NV
                    PRINTVAL NV
                    ECHO -n *
                end ; end if
            ECHO
        end ; end if
        *Get next vector
        nv = nextvector(nv)
        end; end vector loop
    end ; end if
    *Get next plot
    pl = nextplot(pl)
end; end plot loop
ECHO
ECHO
*Print data in output file for SpiceNet to read
setplot ref
echo ##### SENSITIVITY analysis Results #####
#mprint

```

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FIG. 4-3

428

430

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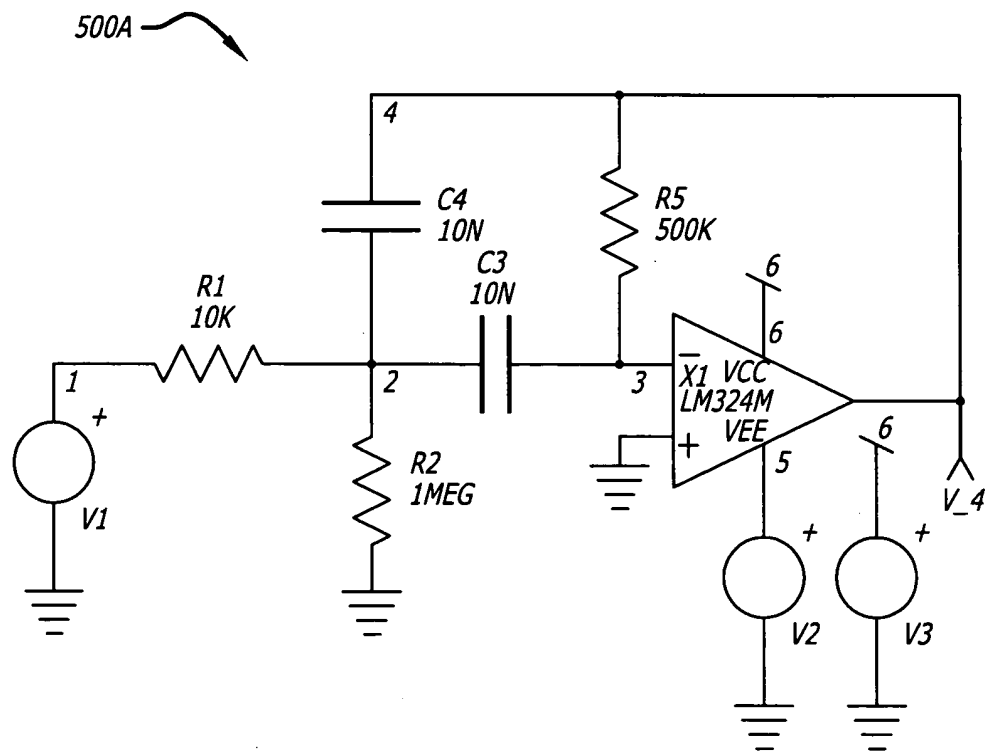


FIG. 5A

C:\spice8d\Circuits\Bandpass.cir Setup1

```

*#save V(2) V(3) @C3[i] @C3[p] V(1) @R1[i] @R1[p] V(4)
*#save @C4[i] @C4[p] @R2[i] @R2[p] @R5[i] @R5[p] V(6) V(5)
*#save @V1[i] @V1[p] @V2[i] @V2[p] @V3[i] @V3[p]
*#alias v_4 v(4)
*#view tran v_4
.TRAN .05ms 20ms
.PRINT AC VDB(4)
.OPTIONS vscale=4
.PRINT TRAN V 4
    
```

502

504

506

500B

FIG. 5B-1

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```
C3 2 3 10N
R1 1 2 10K
C4 2 4 10N
R2 2 0 1MEG
R5 3 4 500K
X1 0 3 6 5 4 LM324M { }
.SUBCKT LM324M 1 2 3 4 5
*
C1 11 12 3.000E-12
C2 6 7 6.000E-12
CEE 10 99 315.8E-15
DC 5 53 DX
DE 54 5 DX
DLP 90 91 DX
DLN 92 90 DX
DP 4 3 DX
EGND 99 0 POLY(2) 3 0 4 0 0.5 5
FB 7 99 POLY(5) VB VC VE VLP VLN 0 53.05E6
+ -50E6 50E6 50E6 -50E6
GA 6 0 11 12 37.70E-6
GCM 0 6 10 99 11.92E-9
IEE 3 10 DC 2.476E-6
HLIM 90 0 VLIM 1K
Q1 11 2 13 QX
Q2 12 1 14 QX
R2 6 9 100.0E3
RC1 4 11 26.53E3
RC2 4 12 26.53E3
RE1 13 10 4.820E3
RE2 14 10 4.820E3
REE 10 99 80.78E6
RO1 8 5 50
RO2 7 99 50
RP 3 4 34.71E3
VB 9 0 DC 0
VC 3 53 DC 2
VE 54 4 DC 5.000E-3
VLIM 7 8 DC 0
VLP 91 0 DC 40
VLN 0 92 DC 40
.MODEL DX D(IS=800.0E-18)
.MODEL QX PNP(IS=800.0E-18 BF=31.58)
.ENDS
V1 1 0 AC=1 PULSE 0 -1 1MS
V2 5 0 DC=-5
V3 6 0 DC=5
.END
```

FIG. 5B-2

 500B

508

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C:\spice8d\Circuits\Bandpass.cir Setup1

.OPTIONS vscale=4

.control

alias v_4 v(4)

view tran v_4

save v(4) — 608

FIG. 6-1

set rewind — 610

set noecho — 612

TRAN .05ms 20ms

set printmode = save

echo TRAN Analysis Measurements

echo

echo Test 1 Mean

homeCursors

print Mean(V(4))

— 614

nameplot ref — 616

SET COLWIDTH=22

SET SPICEDIGITS=5

— 618

printstatus -t #####_sensitivity_for_each_parameter_##### — 620

nextparam null

while param <> null

alterparam tolerance(param)/3

TRAN .05ms 20ms

paramvec = param

printstatus -p paramvec

echo TRAN Analysis Measurements

echo

echo Test 1 Mean

homeCursors

print Mean(V(4))

— 622

nv = nextvector(null)

while nv <> null

if length(nv) = 1

nv = nv - ref.nv

end

nv = nextvector(nv)

end

unalterparam

nextparam

end

↗ 600

```

set printmode = print
unset noecho

pl = nextplot(null)
while pl <> null
  if sameplot(ref.default) = 0

    nv = nextvector(null)

    while nv <> null
      if length(nv) = 1
        if ref.nv <> 0
          nv = (300*Nv)/REF.NV
        else
          nv = 3*Nv
        end
      end
      nv = nextvector(nv)
    end
  end
  pl = nextplot(pl)
end

```

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624

FIG. 6-2

```

printstatus -t #####sorting_sensitivity_for_each_parameter#####
printstatus -t

setplot ref
sort -vd

pl = nextplot(null)
while pl <> null
  if sameplot(ref.default) = 0

    SETPARAM PARAMVEC

    printstatus -p paramvec

    ECHO
    ECHO -u "*****SENSITIVITY DATA*****"
    ECHO
    ECHO -un "PARAMETER NAME: "
    PRINTNAME PARAMVEC
    ECHO
    ECHO -un "NOMINAL VALUE: "
    PRINTVAL PARAMVEC
    ECHO
    ECHO

```

626

628

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```

PRINTTEXT -u VECTOR SENSITIVITY%
ECHO
ECHO

sort -vd
nv = nextvector(null)

while nv <> null
    if length(nv) = 1
        if ref.nv <> 0
            PRINTNAME NV
            PRINTVAL NV
        else
            PRINTNAME NV
            PRINTVAL NV
            ECHO -n *
        end
        ECHO
    end
    nv = nextvector(nv)
end

end
pl = nextplot(pl)
end

ECHO
ECHO

setplot ref
echo ##### SENSITIVITY analysis Results #####
echo TRAN Analysis Measurements
echo
echo Test 1 Mean
homeCursors
print Mean(V(4))

.endc
C3 2 3 10N TOL=5%
R1 1 2 10K TOL=2%
C4 2 4 10N TOL=5%
R2 2 0 1MEG TOL=2%
R5 3 4 500K TOL=2%
X1 0 3 6 5 4 LM324M { }

```

FIG. 6-3

628

630

632

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```
.SUBCKT LM324M 1 2 3 4 5
*
C1 11 12 3.000E-12
C2 6 7 6.000E-12
CEE 10 99 315.8E-15
DC 5 53 DX
DE 54 5 DX
DLP 90 91 DX
DLN 92 90 DX
DP 4 3 DX
EGND 99 0 POLY(2) 3 0 4 0 0.5 5
FB 7 99 POLY(5) VB VC VE VLP VLN 0 53.05E6
+ -50E6 50E6 50E6 -50E6
GA 6 0 11 12 37.70E-6
GCM 0 6 10 99 11.92E-9
IEE 3 10 DC 2.476E-6
HLIM 90 0 VLIM 1K
Q1 11 2 13 QX
Q2 12 1 14 QX
R2 6 9 100.0E3
RC1 4 11 26.53E3
RC2 4 12 26.53E3
RE1 13 10 4.820E3
RE2 14 10 4.820E3
REE 10 99 80.78E6
RO1 8 5 50
RO2 7 99 50
RP 3 4 34.71E3
VB 9 0 DC 0
VC 3 53 DC 2
VE 54 4 DC 5.000E-3
VLIM 7 8 DC 0
VLP 91 0 DC 40
VLN 0 92 DC 40
.MODEL DX D(IS=800.0E-18)
.MODEL QX PNP(IS=800.0E-18 BF=31.58)
.ENDS
V1 1 0 AC=1 PULSE 0 -1 1MS
V2 5 0 DC=-5
V3 6 0 DC=5
.END
```

FIG. 6-4

632

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*****SENSITIVITY DATA*****
PARAMETER NAME: r5
NOMINAL VALUE: 500.00K
VECTOR SENSITIVITY%

mean(v(4)) 1.5111

*****SENSITIVITY DATA*****
PARAMETER NAME: r2
NOMINAL VALUE: 1.0000Meg
VECTOR SENSITIVITY%

mean(v(4)) 17.265M

*****SENSITIVITY DATA*****
PARAMETER NAME: c4
NOMINAL VALUE: 10.0000N
VECTOR SENSITIVITY%

mean(v(4)) -752.77M

*****SENSITIVITY DATA*****
PARAMETER NAME: r1
NOMINAL VALUE: 10.0000K
VECTOR SENSITIVITY%

mean(v(4)) -571.46M

*****SENSITIVITY DATA*****
PARAMETER NAME: c3
NOMINAL VALUE: 10.0000N
VECTOR SENSITIVITY%

mean(v(4)) 4.5201

sensitivity analysis results #####
tran analysis measurements

test 1 mean
mean(v(4)) = 2.086052e-001

Total run time: 0.583 seconds.

Total run time: 0.583 seconds.

Memory remaining = 1996210 Kbytes
Memory Used = 14401 Kbytes

FIG. 7



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RSS, root summed square analysis Simulation Template With Comments:

**Instruct the netlist builder to show tolerances*]- 802
 #tolerance

**Suppress automatic vector saves*]- 804
 #nosave

**Suppress IsSpice4 printout*]- 806
 #noprint

**Save vectors needed for measurements*]- 808
 #vector

**Set the output file pointer to the beginning to remove*]- 810
** the input net list*
 set rewind

**Set the noecho environment for print formatting*]- 812
 set noecho

**Run the specified simulation and save the results*]- 814
 #simulation
 set printmode = save
 #mprint

**Set the print format*]- 818
 SET COLWIDTH=22
 SET SPICEDIGITS=5

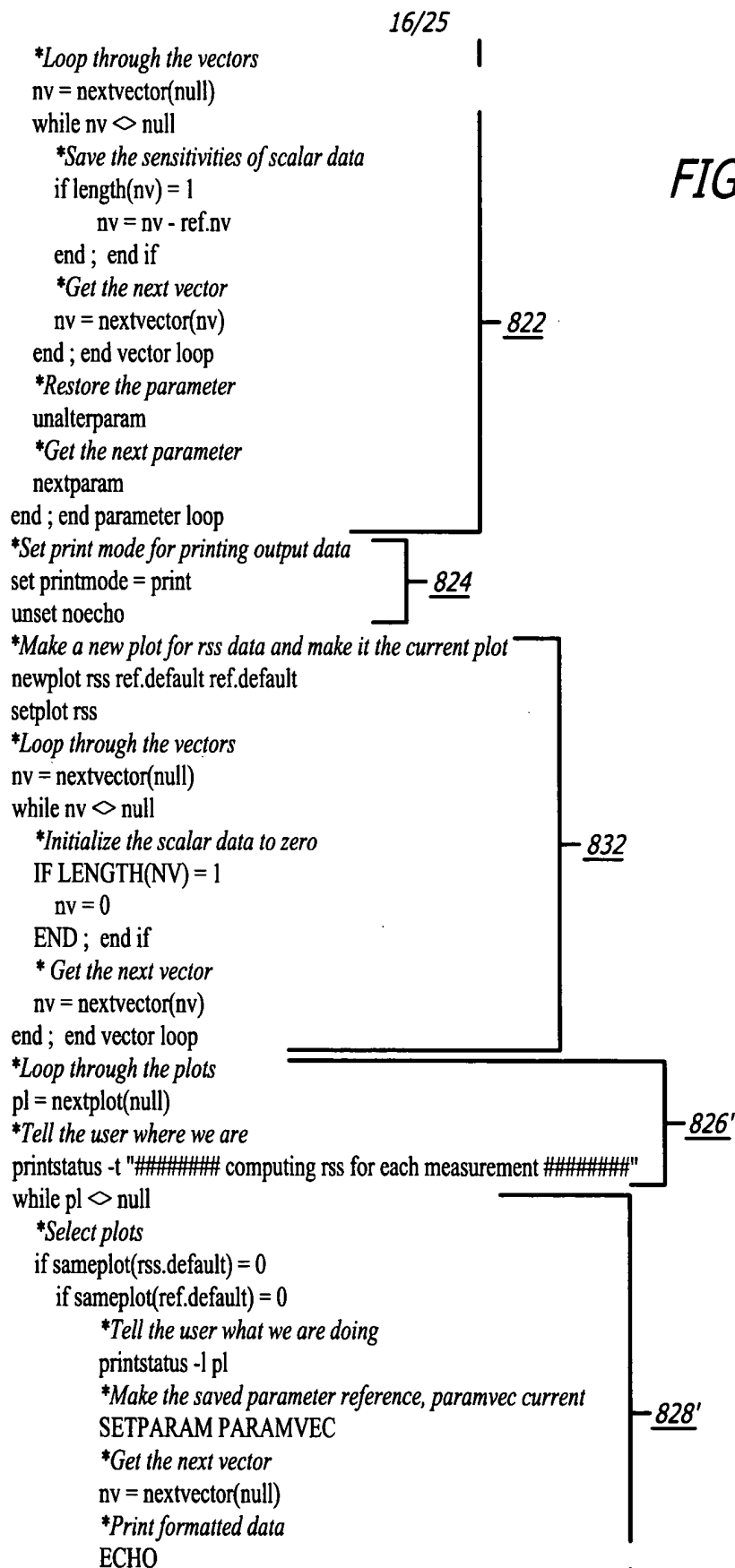
**Rename the simulation plot*]- 816
 nameplot ref

**Loop through all of the parameters*
 nextparam null
**Tell the user where we are*
 printstatus -t "##### sensitivity for each parameter #####"]- 820
 while param <> null
 **Alter each parameter*
 alterparam tolerance(param)/3
 **Simulate*
 #simulation
 **Save the parameter reference in the new plot*
 paramvec = param
 **Tell the user where we are*
 printstatus -p paramvec
 **Save the data*
 #mprint

] 822

FIG. 8-1

800



17/25

```

ECHO -U "*****RSS DATA*****"
ECHO
ECHO -UN " PARAMETER NAME: "
PRINTNAME PARAMVEC
ECHO
ECHO -UN " NOMINAL VALUE: "
PRINTVAL PARAMVEC
ECHO
ECHO -UN "TOLERANCE VALUE: "
PRINTTOL PARAMVEC
ECHO
ECHO
PRINTTEXT -UN VECTOR
PRINTTEXT -U SENSITIVITY% RSS_CONTRIBUTION
ECHO
ECHO
*Loop through vectors
while nv <> null
  if length(nv) = 1
    IF REF.NV <> 0
      *Calculate the RSS percentage if value is not zero
      PRINTNAME NV
      NEWNV = (300*NV)/REF.NV
      PRINTVAL NEWNV
    ELSE
      *Calculate the RSS if value is not zero
      PRINTNAME NV
      NEWNV = 3*NV
      PRINTVAL NEWNV
      ECHO -N *
    END ;end if
    *Save and print the sum of squares
    rss.nv = rss.nv + nv * nv
    PRINTVAL RSS.NV
    ECHO
  end ;end if
  *Get next vector
  nv = nextvector(nv)
end ;end vector loop
* Sort plot by descending value
sort -vd
end ;end if
end ;end if
* Get next plot
pl = nextplot(pl)
end ;end plot loop

```

FIG. 8-3

828'

18/25

```

*Sort the rss plot by descending value
setplot rss
SORT -VD
*Print Headers
ECHO
ECHO -U "*****RSS HI/LO ANALYSIS RESULTS*****"
ECHO
PRINTTEXT -UN VECTOR
SET COLWIDTH=15
PRINTTEXT -U NOMINAL RSS-VALUE TOLERANCE% HI_VALUE LO_VALUE
ECHO
ECHO
*Make a new plot for results
newplot hirss ref.default ref.default
*Loop through the vectors
nv = nextvector(null)
while nv <> null
    if length(nv) = 1
        *Print formatted data
        SET COLWIDTH=22
        PRINTNAME NV
        SET COLWIDTH=15
        PRINTVAL REF.NV
        NV = 3 * SQRT(ABS(NV))
        PRINTVAL NV
        IF REF.NV <> 0
            NEWNV = (100*NV)/REF.NV
        ELSE
            NEWNV = NV*0
        END
        PRINTVAL NEWNV
        NV = REF.NV + NV
        HI_RSS = REF.NV + NV
        LO_RSS = REF.NV - NV
        PRINTVAL HI_RSS
        PRINTVAL LO_RSS
        ECHO
    end ; end if
    *Get next vector
    nv = nextvector(nv)
end; end vector loop
ECHO
ECHO
*Print data in output file for SpiceNet to read
setplot rss
echo ##### RSS HI analysis Results #####
#mprint
RUSAGE ELAPSED

```

834

830'

FIG. 8-4

19/25

EVA, Extreme Value Analysis Simulation Template With Comments:

**Instruct the netlist builder to show tolerances*
#tolerance } 902

**Suppress automatic vector saves*
#nosave } 904

**Suppress IsSpice4 printout*
#noprint } 906

**Save vectors needed for measurements*
#vector } 908

Set the noecho environment for print formatting

set rewind — 910

set noecho — 912

**Run the specified simulation and save the results*
#simulation
pltype = 0 ;Identify the plot type for later use
set printmode = save
#mprint } 914'

**Set the print format*
SET COLWIDTH=22
SET SPICEDIGITS=5 } 918

nameplot ref — 916

newplot evahi ref.default ref.default

evahi.pltype = 0 ;Identify the plot type for later use } 932

**Print status for the user*

printstatus -t "##### sensitivity for each parameter #####" } 920

**Loop through the parameters*

nextparam null

while param <> null

**Alter each parameter*

alterparam tolerance(param)/3

**Simulate, making a new plot for results*

#simulation

**Save the current parameter reference*

paramvec = param } 922'

**Tell the user where we are*

printstatus -p paramvec

**Save the tol and paramval*

paramtol = tolerance(param)

paramval = getparam(param)

pltype = 1 ;Identify the plot type for later use

**Save the simulation results*

FIG. 9-1

900

20/25

```

#mprint
*Loop through all the vectors
nv = nextvector(null)
while nv < null
    *Save the sensitivities for all scalar measurements except pltype
    if length(nv) = 1
        if nv < pltype
            nv = nv - ref.nv
        end ;end if
    end ;end if
    nv = nextvector(nv)
end ;end vector loop
*Restore the param
unalterparam
*Get the next param
nextparam
end;end parameter loop
*Make ref the current plot
setplot ref
*Loop through the vectors in ref
nv = nextvector(null)
*Tell the user where we are
printstatus -t "##### measurements #####"
while nv < null
    if length(nv) = 1
        *Loop through all the plots containing scalar vectors
        pl = nextplot(null)
        while pl < null
            if pltype = 1
                * the inner loop, we are looping through each sensitivity plot looking at the same vector
                * we will alter the parameter id'd by paramvec to maximize/minimize the vector
                setparam paramvec
                *Change each parameter to its worst case extreme value
                if nv >= 0
                    alterparam paramtol
                else
                    alterparam -paramtol
                end
            end
            pl = nextplot(pl)
        end
        *Simulate for the extreme case and save the data in a new plot
        #simulation
        #mprint
        pltype = 2 ;Identify the plot type for later use
    * if we want sensitivity at the extreme, we need to go through each param
    * and change it to be a bit different than it is at the extreme, run a simulation ,

```

FIG. 9-2

922'

934

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** and mark it as pltype 3 along with its paramvec, then we can take the diff*
** from the pltype = 2 to get the sensitivity at the extreme if the sign at the extreme*
** is different than at the nominal, we can report an error or go on to do worst case*
** for worst case, we need to reduce the param change by 1/2 and do this over again...*
** either continue in this loop or make a wc loop afterward... save the paramvalue*
** and tolerance*

evahi.nv = nv
if nv \diamond pltype
**Tell the user where we are*
printstatus -n nv
end ;endif
end ;end plot loop
;get the next vector
nv = nextvector(nv)

end ;end vector loop

**Set print mode and print header*

set printmode = print

unset noecho

setplot EVAHI

ECHO

ECHO -U "*****EVA PARAMETER LIST*****"

ECHO

PRINTTEXT -UN PARAMETER

PRINTTEXT -U NOMINAL TOLERANCE

ECHO

ECHO

**Loop through the parameters*

nextparam null

while param \diamond null

**Extract the saved param reference and print its data*

paramvec = param

PRINTNAME PARAMVEC

PRINTVAL PARAMVEC

PRINTTOL PARAMVEC

ECHO

**get the next param*

nextparam

end ;end param loop

ECHO ;print a blank line

**Make a new plot to hold sorted results*

newplot evasort ref.default ref.default

**Make ref the current plot*

setplot REF

**Loop through all vectors in ref*

nv = nextvector(null)

while nv \diamond null

if length(nv) = 1

934

FIG. 9-3

936

938

22/25

```

*save the result in evasort as a percent of its value
if ref.nv < 0
    evasort.nv = ((evahi.nv-ref.nv)*100)/ref.nv
else
    evasort.nv = 0;
end ;end if
end ;end if
*Get the next vector
nv = nextvector(nv)
end ;end vector loop
*Print some headers
ECHO
ECHO -U "*****EVA-HI RESULTS*****"
ECHO
PRINTTEXT -UN VECTOR
PRINTTEXT -U NOMINAL EVA-HI CHANGE%
ECHO
ECHO
setplot evasort
*Sort evasort by descanting data
sort -VD
*Loop through the vectors
nv = nextvector(null)
while nv < null
    *If its the correct data in the correct plot, print it
    if length(nv) = 1
        if nv < pltype
            PRINTNAME NV
            PRINTVAL REF.NV
            PRINTVAL EVAHI.NV
            PRINTVAL EVASORT.NV
            ECHO
        end ; end if
    end ; end if
    *Get the next vector
    nv = nextvector(nv)
end ; end vector loop
ECHO
ECHO

* now the eva results are in pltype = 2 plots
*Print the results so SpiceNet can read the eva-hi data
set printmode = print
unset noecho
setplot evahi
echo ##### EVA HI analysis Results #####
#mprint

```

FIG. 9-4

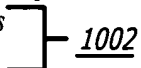
938

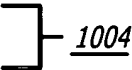
940

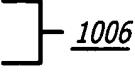
930'

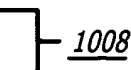
WCS, Worst Case by Sensitivity Simulation Template With Comments:

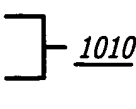
23/25

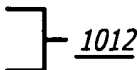
**Instruct the netlist builder to show tolerances*
 #tolerance  1002

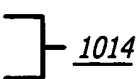
**Suppress automatic vector saves*
 #nosave  1004

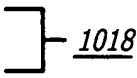
**Suppress IsSpice4 printout*
 #noprint  1006

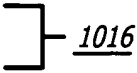
**Save vectors needed for measurements*
 #vector  1008

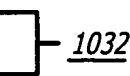
**Set the output file pointer to the beginning to remove
 * the input net list*
 set rewind  1010

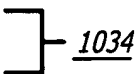
**Set the noecho environment for print formatting*
 set noecho  1012

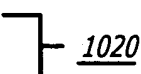
**Run the specified simulation and save the results*
 #simulation  1014
 set printmode = save
 #mprint

**Set the print format*
 SET COLWIDTH=22  1018
 SET SPICEDIGITS=5

**Rename the simulation plot*
 nameplot ref  1016

**Make a newplot for results*
 newplot result ref.default ref.default  1032

**Set the current plot to ref*
 setplot ref  1034

**Print status for the user*
 printstatus -t "##### sensitivity for each parameter #####"  1020

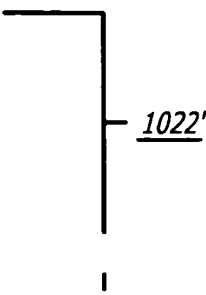
**Loop through the parameters*
 nextparam null
 while param < null
 **Alter each parameter*
 alterparam tolerance(param)/3
 **Simulate, making a new plot for results*
 #simulation
 **Save the current parameter reference*
  1022'

FIG. 10-1

 1000

```
paramvec = param
*Inform the user about what's being done
printstatus -p paramvec
*Make and save the measurements
#mprint
*Loop through the vectors
nv = nextvector(null)
while nv <> null
    *Save the sensitivity of scalar quantities
    if length(nv) = 1
        nv = nv - ref.nv
        *Save the worst case -hi value
        result.nv = result.nv + abs(3*nv)
    end ;end if
    nv = nextvector(nv)
end ;end vector loop
*restore the parameter value
unalterparam
*get the next parameter
nextparam
end ;end parameter loop
```

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FIG. 10-2

1022'

```
*Set the print mode to print instead of save
set printmode = print
*Restore the echo mode for printing
unset noecho
*Set result to the current plot
setplot result
*Print the header
ECHO
ECHO -U "*****WCS PARAMETER LIST*****"
ECHO
PRINTTEXT -UN PARAMETER
PRINTTEXT -U NOMINAL TOLERANCE
ECHO
ECHO
*Loop through the parameters
nextparam null
while param <> null
    paramvec = param
    *Print the row
    PRINTNAME PARAMVEC
    PRINTVAL PARAMVEC
    PRINTTOL PARAMVEC
    ECHO
    nextparam
end
ECHO
```

1036

```

*Make a new plot to hold sorted results
newplot wcsort ref.default ref.default
*Set the current plot to ref
setplot REF
*Loop through its vectors
nv = nextvector(null)
while nv <> null
    *Calculate the wc as a percent change results
    if length(nv) = 1
        if ref.nv <> 0
            wcsort.nv = ((result.nv-ref.nv)*100)/ref.nv
        else
            wcsort.nv = 0;
        end ;end if
    end ;end if
    nv = nextvector(nv)
end ;end vector loop

```

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FIG. 10-3

1038

```

*Print headers
ECHO
ECHO -U "*****WCS-HI RESULTS*****"
ECHO
PRINTTEXT -UN VECTOR
PRINTTEXT -U NOMINAL WCS-HI CHANGE%
ECHO
ECHO
;sort wcsort by descending value
setplot wcsort
sort -VD
*Print the ordered list
nv = nextvector(null)
while nv <> null
    if length(nv) = 1
        PRINTNAME NV
        PRINTVAL REF.NV
        PRINTVAL RESULT.NV
        PRINTVAL WCSORT.NV
        ECHO
    end
    nv = nextvector(nv)
end
ECHO
ECHO

```

1040

```

*Set the current plot to the wc results
setplot result
echo ##### WCS HI analysis Results #####
*Print the measured results in a form that can be read back into SpiceNet
#mprint
*Report the elapsed time in the output file
rusage elapsed

```

1030'